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Meteorological Observations in a Potato Crop

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Summary

Air, soil and crop canopy temperatures were automatically recorded each hour in a field of maincrop potatoes during June to August 1984. The air temperatures, and the departures of the canopy and soil temperatures from that of the air, are presented. Rainfall observations, calculated values of soil moisture deficit and estimates of sunshine are included. Methods for using meteorological recordings to estimate yields are discussed.

Introduction

Crop growth, yield and diseases are being increasingly monitored using biologically and physically based models. The soil temperature and the air and/or crop canopy temperatures are some of the key inputs to these models.

The soil temperature at one or more standard depth is routinely measured at 0900 GMT at about 200 locations in England and Wales. Relationships between the 0900 GMT and the maximum and minimum soil temperatures were developed by Gloyne (1950) from readings taken in an uncropped deep sandy loam soil. Hirst and Steadman (1960) measured the temperature and relative humidity of the air within and above potato crops throughout the growing seasons of 1951 to 1958. These data have been used by numerous researchers, including Sparks (1984) who produced an updated potato blight prediction model.

The results presented in this paper add to the bank of data and may be specifically relevant because of the favourable weather conditions for high yields.

The monitoring was carried out as a contribution towards a national survey of potato crops under the direction of the Scottish Crops Research Institute.

Method

Three thermistor temperature probes were positioned in a field of maincrop potatoes, cv Maris Piper, late in May 1984. The field slopes gently to the SE and the soil is a deep silty clay loam of the Bromyard series, prone to cracking in dry conditions. The position of the thermistors were as follows:-

1. Crop canopy temperature: probe housed in a white shielded mount ("cocoa tin" type) on top of a ridge.

2. Soil temperature: probe buried 10 cm below the top of a ridge.

3. Air temperature: probe housed in a "cocoa tin" mount 1.2 m above the ground at the edge of the field.

The field was planted on the 17/18 April. Emergence began around the 23 May and by 20 June the crop was meeting within the rows (25% ground cover). By 13 July the crop was meeting between the rows (80% cover) and the haulm was burned off on the 15 September with an estimated 75% of green leaf still present. On the 17 November three, 3 m long rows were lifted to provide a yield estimate for the field. The bulk of the crop was not lifted until mid December due to wet ground conditions.

Results

1. Air temperature

The weekly averaged air temperatures are shown in fig. 1a. The mean temperature was seldom below the long term average area value, and often 2 to 4°C above it. Some of this increase will have been due to the SE aspect of the field. In terms of accumulated temperature the 3 month total above a base of 0°C was 1534 °C days which compares to a long term average of 1394 °C days (ie a 10% increase, equivalent to an increase in the mean temperature of 1.6°C).

2. Air to Canopy Temperature

As measured in terms of weekly averaged maximum, minimum and mean, the temperature within the crop was invariably higher than that of the air. The difference in the mean gradually fell from around 1°C to around 0°C as the canopy developed. Larger differences were found in 1) the daily maximums* which were generally 1 to 3½°C warmer in the partial canopy, but

falling to near parity with a full canopy, and 2) the minimum* which was very close to the air min with a partial canopy, but around 1 to 2°C warmer after 50% crop cover was attained (see fig. 1 b-d).

These differences are similar to, but a little smaller than, those observed by Hirst et. al. where the maximum canopy temperature exceeded that in the air by 5°C initially but reduced to 1°C with a full crop canopy. This is consistent with the fact that Hirst measured in crop temperatures between ridge and trough.

3. Air to Soil Temperature

With a sparse cover, the 10 cm soil temperature under the crop tended to be warmer than the air temperature (max. min and mean daily values). With greater leaf development (>25% ground cover) the max. soil temperature rapidly fell, relative to that of the air max., and untimately was around 6°C below the air max.(fig 2c). However, the soil min. was above the air min by between 2 and 8°C (Mean 4½°C), fig 1d. Therefore the mean daily temperatures 10 cm under the top of the ridge were warmer by 1° to 3°C while the crop was achieving a full canopy, before falling to near parity thereafter, (fig.1 b). Comparing the values taken 10 cm under bare soil given by Gloyne (1950) it seems that the Clifton values under a sparse crop in June are similar. An average of 8.4°C between the monthly averaged max and min compares to Gloyne's summer range of "8 to 10°C". With an increasing leaf cover the mean monthly range rapidly decreased under the potato crop to 5.4°C (July) and 3.4°C (August), see table 1. Similarly, like Gloyne, the 0900 GMT spot reading was close to the minimum recorded over the previous night. The effect of shading and a progressively later sunrise is shown with the difference (Tn - To9) decreasing from a monthly mean of 1°C (June) to 0.3°C (August). See fig 2.

Table 1. Monthly mean temperatures (°C). Clifton-on-Teme.

	Air			Canopy			10 cm Soil			
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	0900
June	15.3	22.2	9.5	16.0	23.5	9.9	17.6	22.2	13.8	14.8
July	17.6	25.6	10.6	18.6	26.7	12.3	18.9	21.7	16.3	16.7
Aug.	17.9	25.0	12.6	18.1	25.0	16.9	17.3	19.0	15.6	15.9

4. Rainfall and Soil Moisture Levels

The months of May to August were drier than average whilst September was very wet, see Table 2.

Table 2. Monthly Rainfall Totals for Clifton-on-Teme: 1984 (mm)*

	May	June	July	Aug	Sept	Total
1984	47.6	39.5	22.0	52.5	108.1	269.7
% of average	75	82	39	70	183	89%

*Raingauge sited within the field and read daily.

With September accounting for 40% of the rainfall total and July being particularly dry (17.5 mm of the 22.0 mm total fell on the 12th), the summary of rainfall conceals many long, dry spells. The calculation of soil moisture deficit (Spackman, 1983) illustrates the very intermittent nature of the summer rainfall: see fig. 3.

5. Sunshine

Neither sunshine nor solar radiation were recorded on site. Good estimates of weekly total sunshine hours may be extracted from the MORECS data for the area: Table 3.

Table 3. Sunshine Estimates for Clifton-on-Teme area: 1984 (hrs/month)

	May	June	July	Aug	Sept	Total
1984	178	213	290	208	126	1015
% of average	94	107	156	122	100	117%

Thus there was a 17% increase in the seasonal total and approximately an 8% increase in incident short wave solar radiation. The benefits of above average solar radiation in terms of transpiration, photosynthesis, crop growth and ultimately yield can be gauged from data quoted by Allen and Scott (1980) and Tanner (1981): see section 7.

6. Response of the Crop to Rainfall

In general, meteorological factors were favourable for the potato crop. The rainfall during late May and early June aided emergence and establishment. By mid to late June the crop was meeting within the rows and the underlying soil surface was very dry. The calculated SMD for the 30 June indicates that the crop had extracted 50 mm of moisture, 55% of the total available. Continued rapid growth during early July drew heavily on soil moisture reserves so by the 11th some 74% of the available moisture had been extracted from the soil profile. Many cracks were by now visible on the soil surface. The heavy rainfall in mid July replenished moisture reserves but considerable stress was again evident by late July (88% extracted). The pattern was repeated until further rain during mid September, combined with lower evaporation losses, supplied adequate moisture to the crop.

Although rainfall was insufficient to satisfy the demands of the crop for several periods during the season sufficient growth was achieved early on to well utilise the very high values of solar radiation during July and August especially. This higher than average assimilation of solar radiation combined with the high AWC of the soil (120 mm) allowed the crop to bulk and produce a high yield (53.4 t/ha). However, the very intermittent nature of the summer rainfall caused uneven growth and considerable splitting of the tubers and a high incidence of common scab. (Wolfe et. al, 1983).

7. Yield Estimates

The fresh tuber yield in the trial field was measured on the 17 November at 53.4 tonnes per hectare. At a second trial site one mile away, and on a similar soil, the yield was 58.0 t/h measured on the 25 October. In this area yields are normally around 40 t/h for main crop potatoes on a silty clay loam soil. Therefore the yields were well above average despite the lower than average summer rainfall. The reason for this apparent contradiction can be found by examining the two techniques commonly employed to estimate crop yields.

Daily values of solar radiation can be used to estimate gross photosynthesis and dry matter accumulation of the crops. Also necessary are detailed observations of leaf area index so that the fraction of the

solar beam in the photosynthetically active part of the specturm (approx. 50% of the total solar radiation) which is intercepted by the foliage can be estimated. Relationships between intercepted solar radiation and crop yield have been published for potatoes (Allen and Scott, 1980) and for the sugar yield of beet (Scott et al, 1973). However, this approach takes no account of yield limitations due to moisture stress and further, due to the exacting and complex procedure needed to determine the input data this method is better suited to fine detail computer models rather than field trial results.

Alternatively, a yield estimate for a crop can be given by the accumulated moisture consumption (ie accumulated transpiration) over the growing season. Transpiration is directly related to the translocation of minerals and nutrients to the plant and several relationships between transpiration, photosynthesis, dry matter accumulation and hence yield have been published. The daily calculation of transpiration will include the contribution from solar radiation as well as that from temperature, humidity, windspeed and also soil moisture availability. Tanner (1981) presenting data collected from main crop potatoes, cv Russet Burbank, in Winconsin, USA, correctly uses estimates of transpiration (rather than evapotranspiration which additionally includes (usually small) evaporation losses fom the soil and intercepted rainfall on the foliage) to derive a transpiration vs yield relationship; see fig 4. Tanner also presents his yields in terms of transpiration per unit saturation vapour deficit (mm/mb) which produces an improved fit to the data; see fig 5.

There are similarities between the data of Tanner and the results from the trial site at Clifton. However, the actual evapotranspiration (AE) losses calculated for 1984 were only near or rather below the average while the crop yield was well above average. This is due to the dominant influence of rainfall in the AE calculation. The important contribution from solar radiation (ie available energy) is made a secondary effect in Tanner's method, as is the available water content (AWC) of the soil.

An alternative to solar radiation as a measure of the available energy can be found in the calculation of potential evapotranspiration (PE). A simple scheme combining 1) the water use of the crop with 2) the energy available to the crop, encompasses the two principle features of crop growth. In Britain, potential and actual evapotranspiration values for a wide range of crops and soils are already calculated on a daily basis for the weekly

MORECS[+] bulletins. To process the MORECS model output for potatoes, following Tanner (1981) would be a logical extension of the existing service. Naturally, a prerequisite of this idea would be the analysis of past and future field trial data with different crops, varieties and soils in order to establish precise relationships applicable to our crops and climate. There is an abundance of literature to show that similar transpiration - yield relationships exist for crops other than potatoes vis a vis winter wheat (Green et al, 1983), vegetables (Greenwood et al, 1977; Greenwood and Rowse, 1981) and sugar beet (Draycott and Messem, 1977). Indeed, as the whole principle of irrigation is based on optimising the moisture consumption of a crop this would provide a source of data in which the available energy (ie PE) is a key factor in the determination of yield. Thus, providing that the agronomic management of the crop has been adequate, an approach of this type could provide real-time "target" yields for a variety of crops in any season (irrigated or non-irrigated). Where there were large deviations from the target yield, agronomic, rather than meteorological, explanations must be sought.

Conclusions

1. Mean temperatures recorded within a potato canopy, and in the underlying soil, were generally warmer than those recorded in the ambient air. The differences of 1° to 3°C gradually diminished as the canopy grew more dense. The most marked effect was on the daily maximum soil temperatures which rapidly fell (relative to that of the air) as the canopy developed.

2. Rainfall was observed to be below average for much of the summer and very intermittent in nature. Calculations of soil moisture deficit indicate several periods of crop stress between heavy rainfall events causing splitting of the tubers and widespread common scab.

3. Good emergence and a rapidly expanding crop canopy during June enabled the crop to intercept a greater fraction of the very high levels of incident solar radiation noted during July and August. This contributed to the ultimately high yield of the crop.

[+]The Met. Office Rainfall and Evaporation Calculation System (Thompson et al, 1981)

4. The seasonal relationships between accumulated transpiration and crop yield show considerable promise and further development could lead to an operational scheme to provide "real-time" yield estimates for a wide range of crops.

Key Words. Potatoes, air and soil temperature, soil moisture deficits, transpiration, yield estimates.

Any comments or suggestions relating to this paper should be addressed to the author.

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25 January 1985.

Footnote:

*The max and min values quoted here are the highest and lowest of the 24 hourly values each day. The empirical correction to the "true" max and mins has not been applied (Collison and Tabony, 1983) as it would only be applicable to the air temperatures.

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CLIFTON TEMPERATURES
WEEKLY MEANS: 1984.

Figure 1.

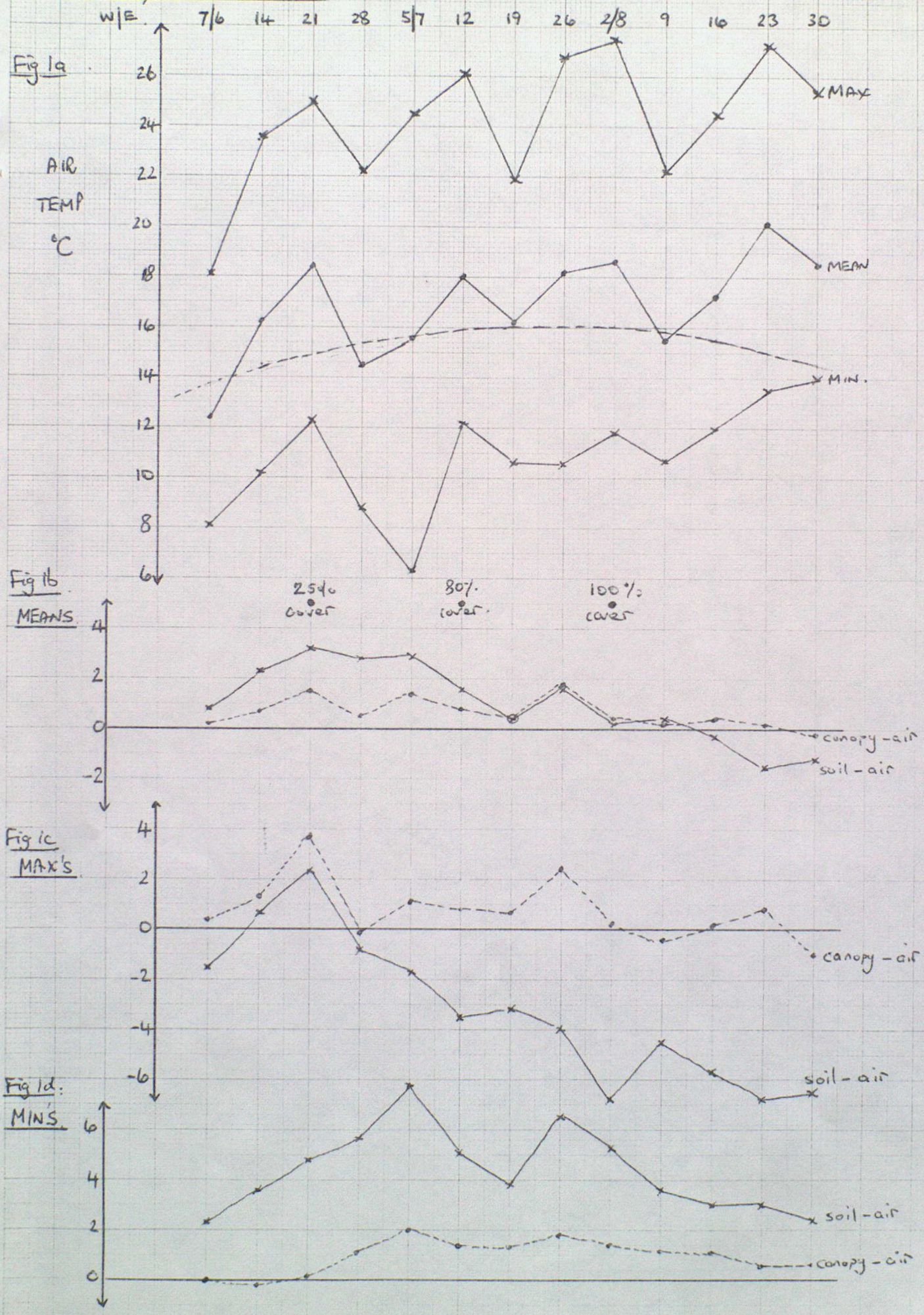
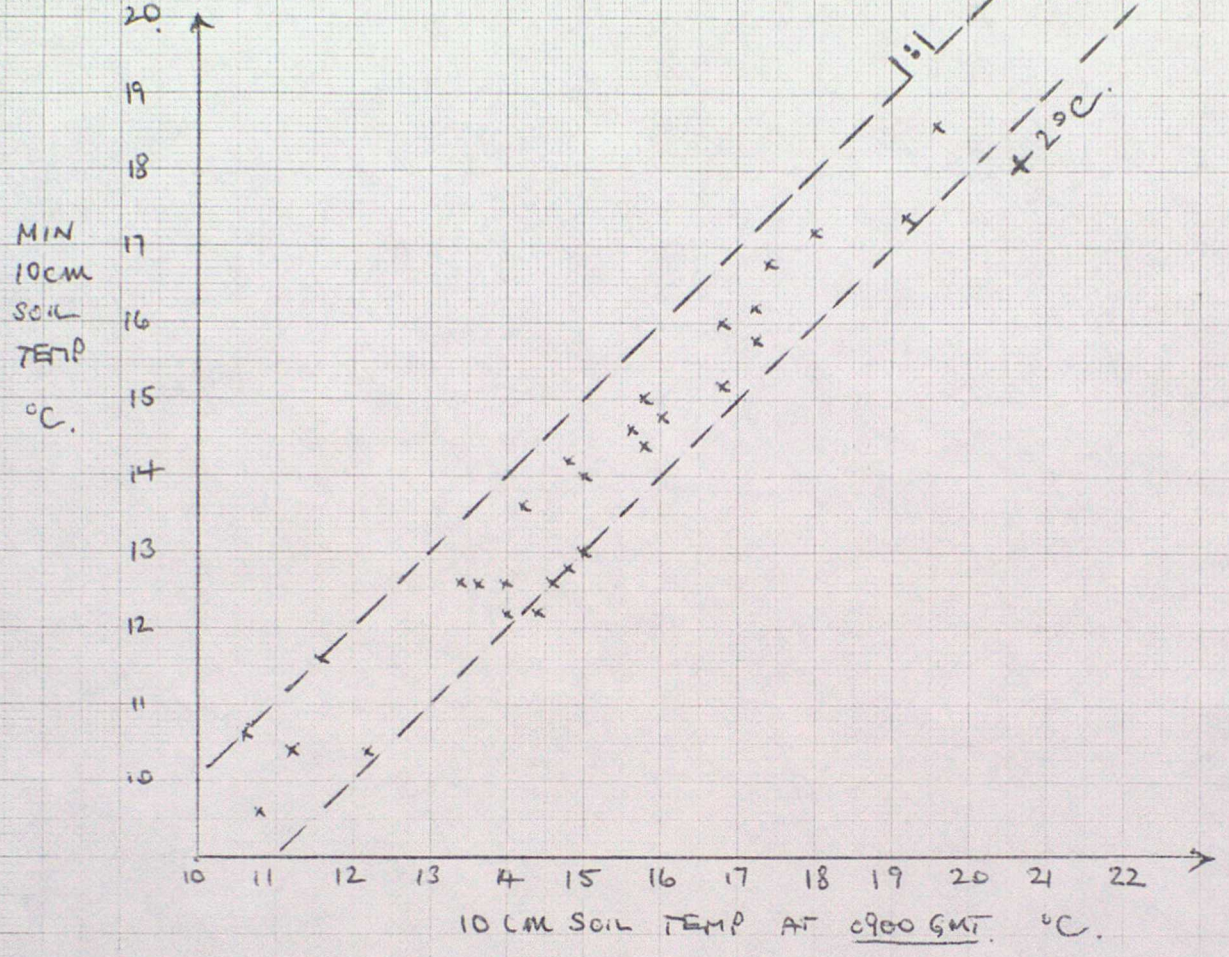


Fig. 2.

SOIL TEMP AT 0900GMT RELATIVE TO THE MIN
CLIFTON JUNE 1984.



CLIFTON JULY 1984.

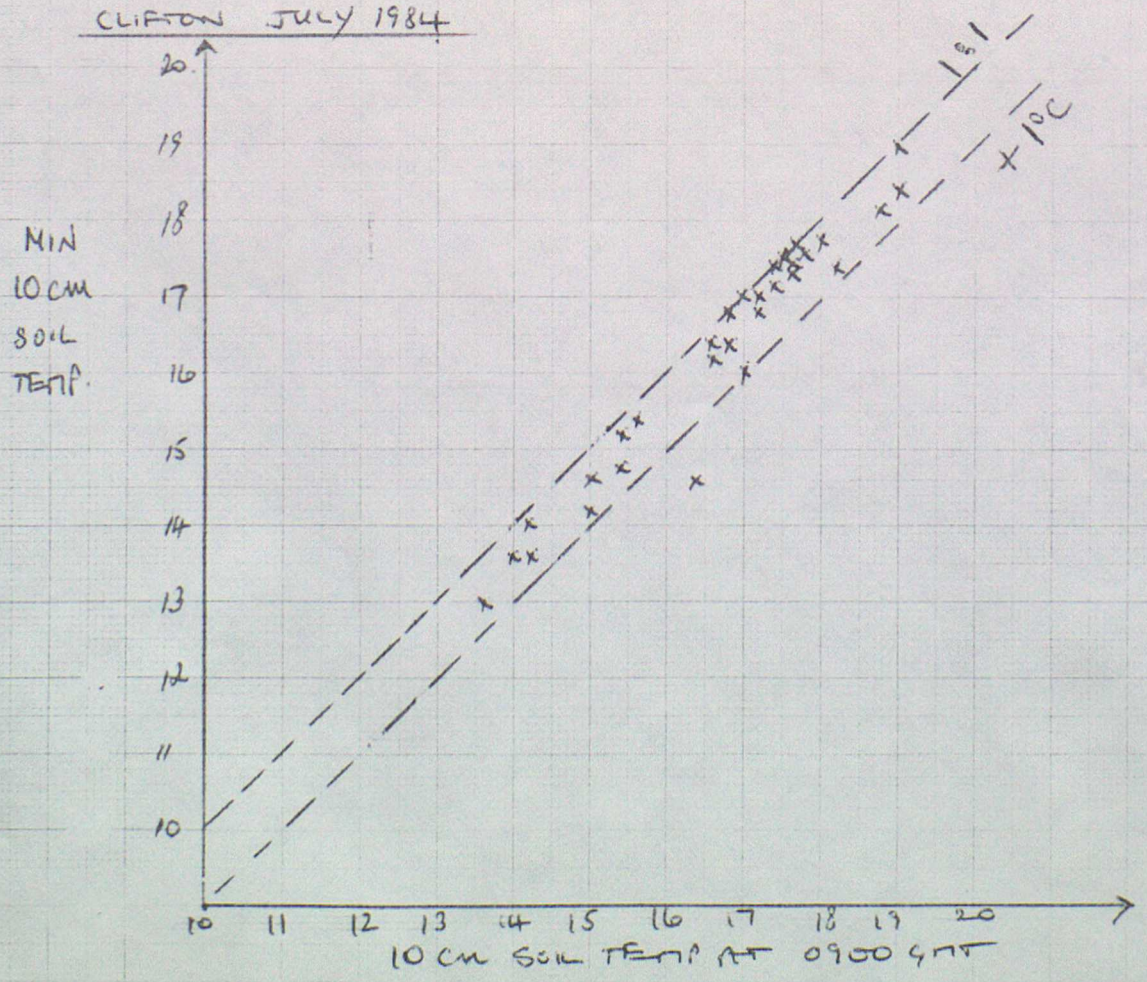
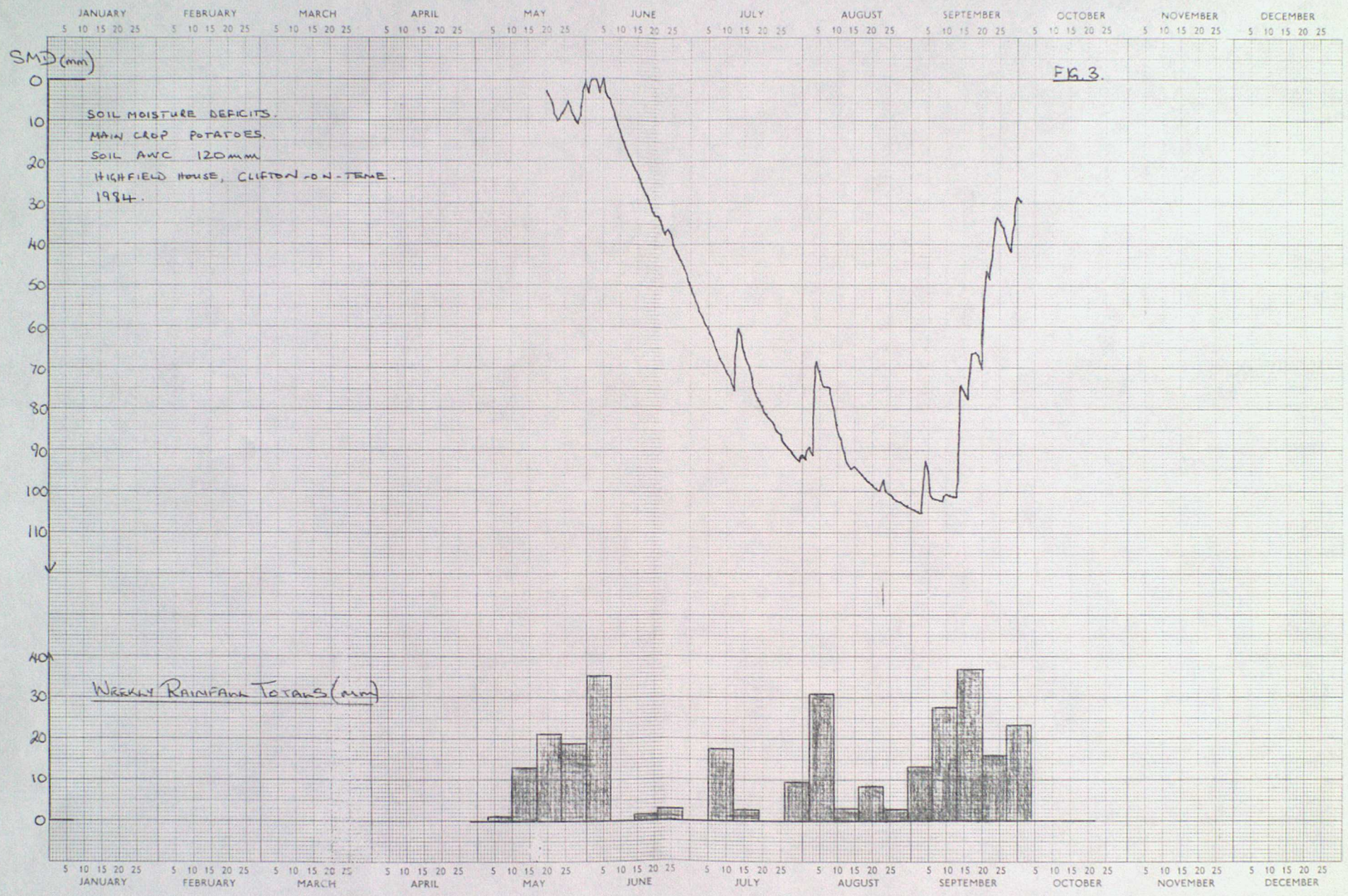


FIG. 3.

SOIL MOISTURE DEFICITS.
MAIN CROP POTATOES.
SOIL AWC 120mm
HIGHFIELD HOUSE, CLIFTON-ON-TERME.
1984.



Chartwell Graph Data Ref. 4057
200 Equal Divisions x One Year (366 days)
H.59141L

Fig.4

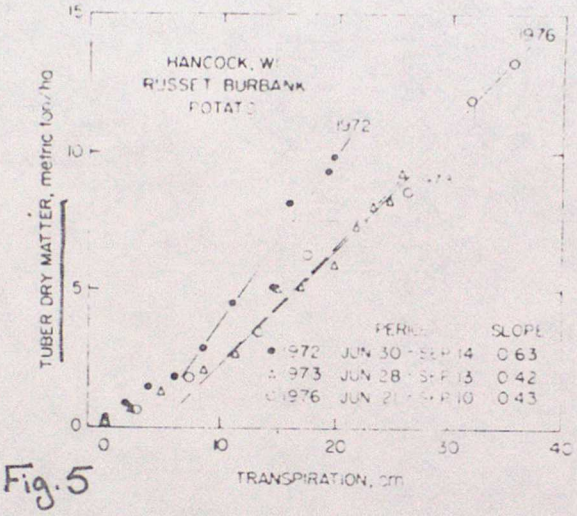


Fig.5

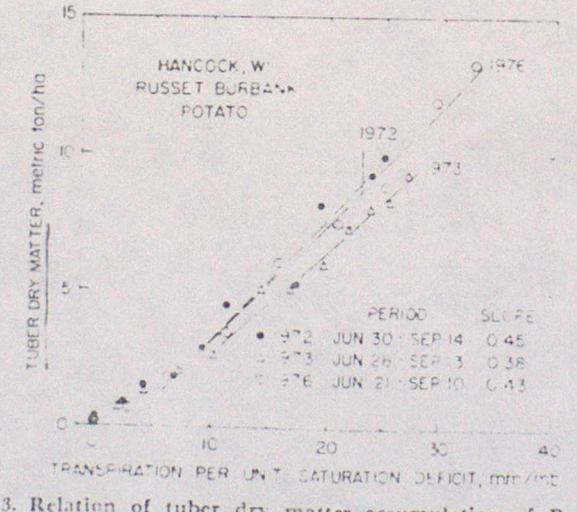


Fig. 3. Relation of tuber dry matter accumulation of Russet Burbank potato to transpiration [top] and T/(e*−e) [bottom]. Lines are fitted to the "linear" tuber growth phase.

(Tanner, 1981)

1 tonne tuber dry matter ≃ 5 tonnes fresh weight.